Mars-Moon Exploration, Reconnaissance, and Landed Investigation

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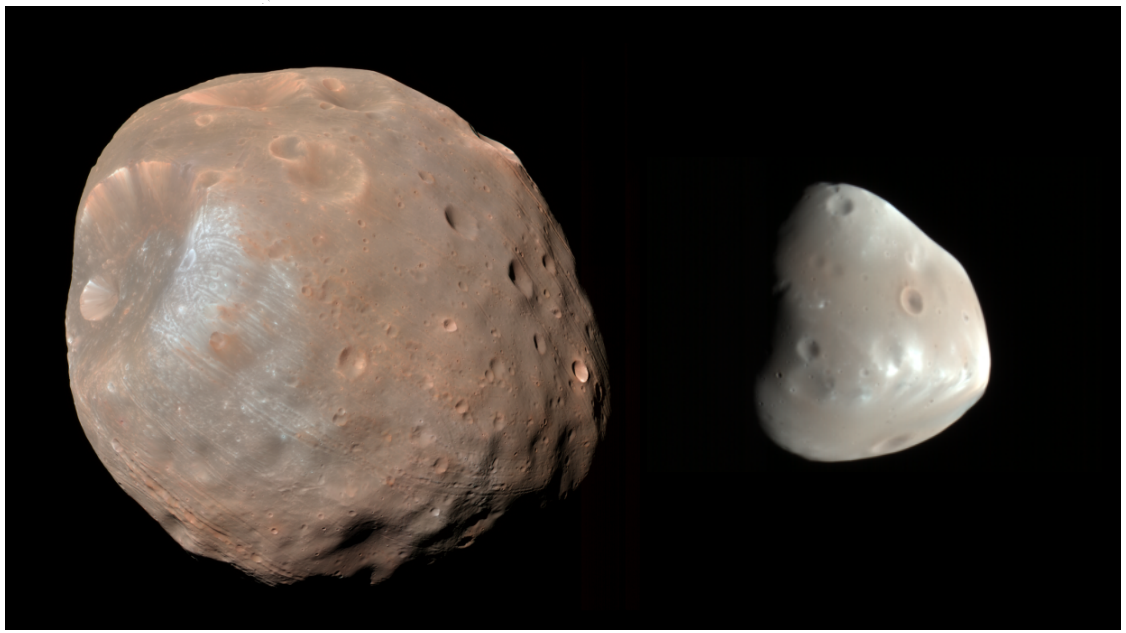
APL JPL Washington University in St. Louis

Phobos and Deimos



	Phobos	Deimos
Size	27 x 21 x 19 km	15 x 12 x 10 km
Orbital Period	7.66 hrs	30.3 hrs
Density	1.9 g/cm^3	1.5 g/cm^3
Semi-major axis	9,377 km (2.8 R_{Mars})	23,460 km (~7 R_{Mars})
Gravity	2-8 x 10^{-3} m/s^2	2 x 10^{-3} m/s^2

- …Are the only terrestrial planet satellites besides the Moon
- Therefore they provide insights into terrestrial planet formation
- Reconnaissance by several missions gives us a working knowledge of the moons' outstanding science issues

Spectral Properties

- Very low albedo
- Reddish
- No sign of bound water, OH, or organics

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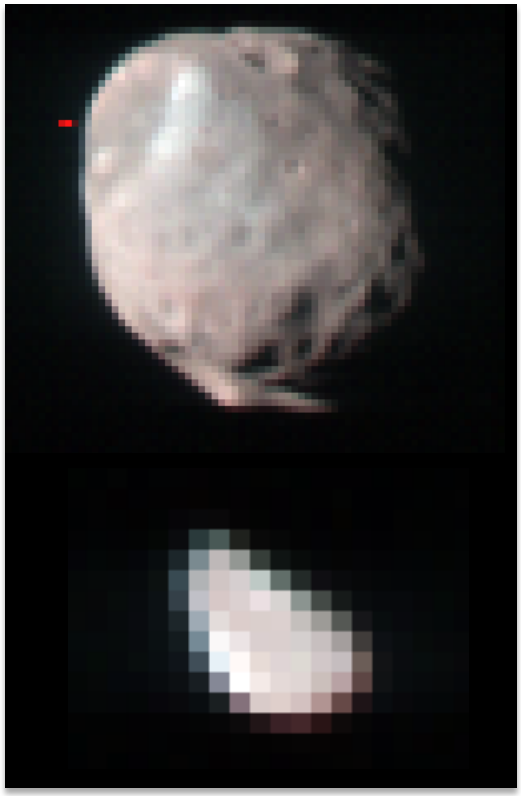

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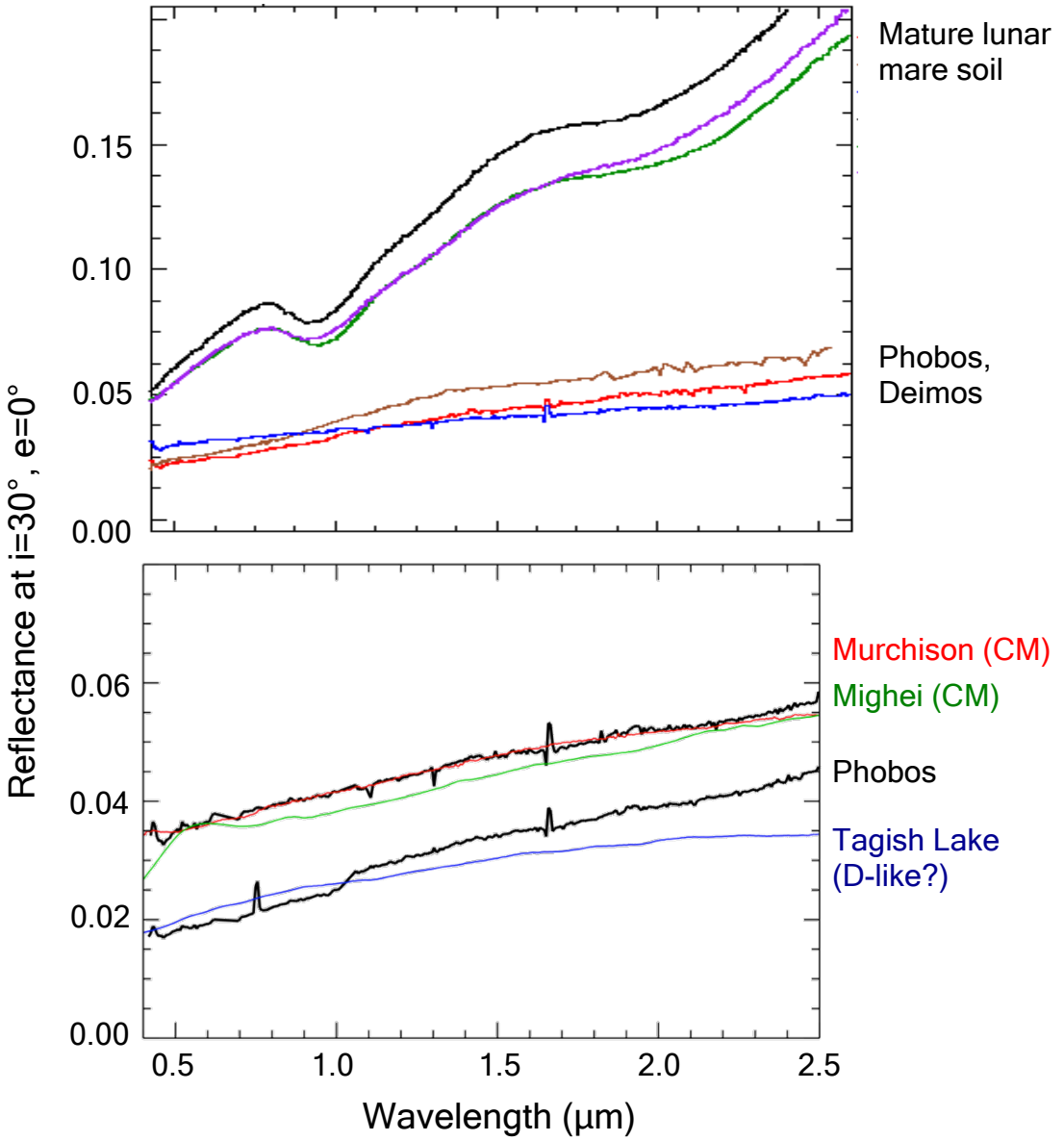
From: Fraeman et al. (2012)



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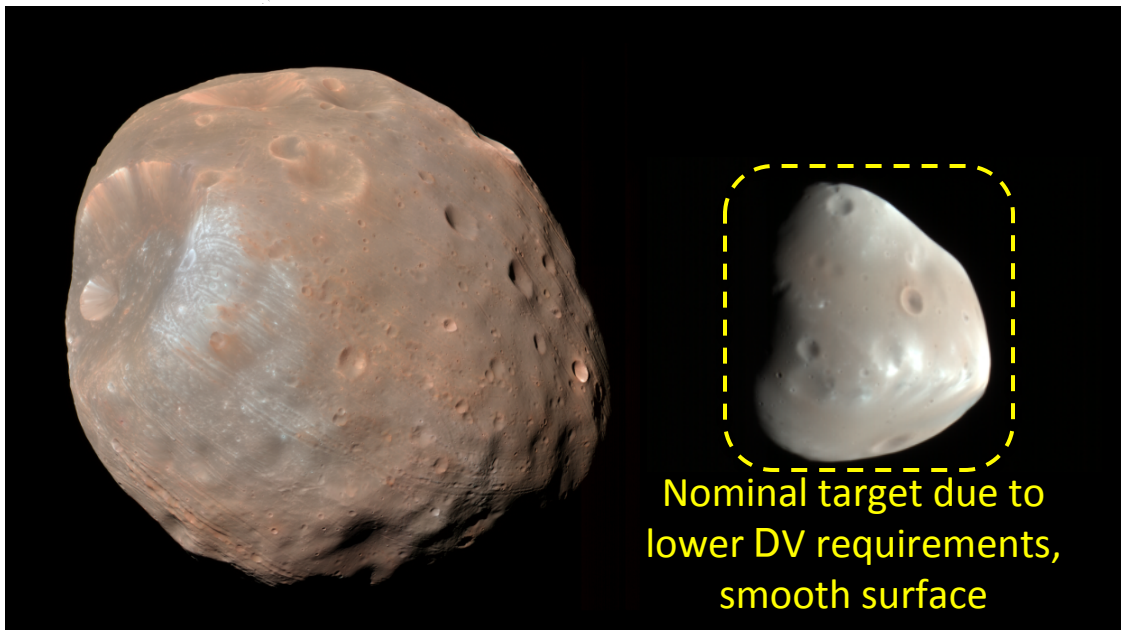
Phobos and Deimos Science Drivers



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1) Composition and origin unknown – a record of the early Mars system lost from Mars' surface

2) Possibly C rich – insight into origin of terrestrial planet C (and volatiles?)

3) A laboratory for small-body geologic processes

MERLIN Questions

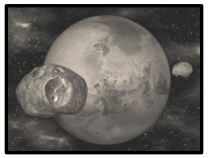
What are the origins of Phobos and Deimos?

Primitive material

Plus
- Explains low r, albedo
- Explains similarity to D-type asteroids

Minus
- Capture from outside Mars system hard to explain

Formed from Mars material



Plus
- Explains the orbits if formed by co-accretion

Minus
- Does not explain low albedo

Depending on the origin, a different composition is expected!

Origin Hypothesis	Composition Predicted	Elemental abundances	Mineral abundances
Capture of organic- and water-rich outer solar system body	Ultra-primitive composition; Tagish Lake is the best known analog	High C; high Zn/Mn; high S; composition possibly distinct from known meteorites	Abundant phyllosilicates; carbonates and organic phases; anhydrous silicate phases rare
Capture of organic and water-poor outer solar system body	Anhydrous silicates plus elemental C	High C; Mg/Fe ratio ~2–4; bulk composition unlike any meteorite analogs	Anhydrous, med. Fe (20–40%) pyroxene; abundant amorphous C or graphite?
Capture of inner solar system body	Composition like common meteorites (e.g., ordinary chondrites)	Mg/Si ~0.8–1, Al/Si ~0.05–0.1; Zn/Mn and Al/Mn ratios separate known meteorites; low C	Low carbonates, phyllosilicates; pyroxene, olivine probably in range of known meteorites
Co-accretion with Mars	Bulk Mars; similar to ordinary chondrites but specific SNC-derived composition	Mg/Si, Al/Si, Fe/Si indicative of bulk Mars; low C; Zn/Mn, Al/ Mn like ordinary chondrites	Anhydrous silicates with Fe, Mg expected for bulk Mars; low abundance of C-bearing phases
Giant impact on Mars	Evolved Martian crust or mantle, like SNC meteorites, Mars rocks or soil	High Al/Si, Ca/Si, lower Fe/Si, Mg/Si indicative of evolved igneous materials	Evolved, basaltic mineralogy consistent with many datasets for Mars

MERLIN Questions

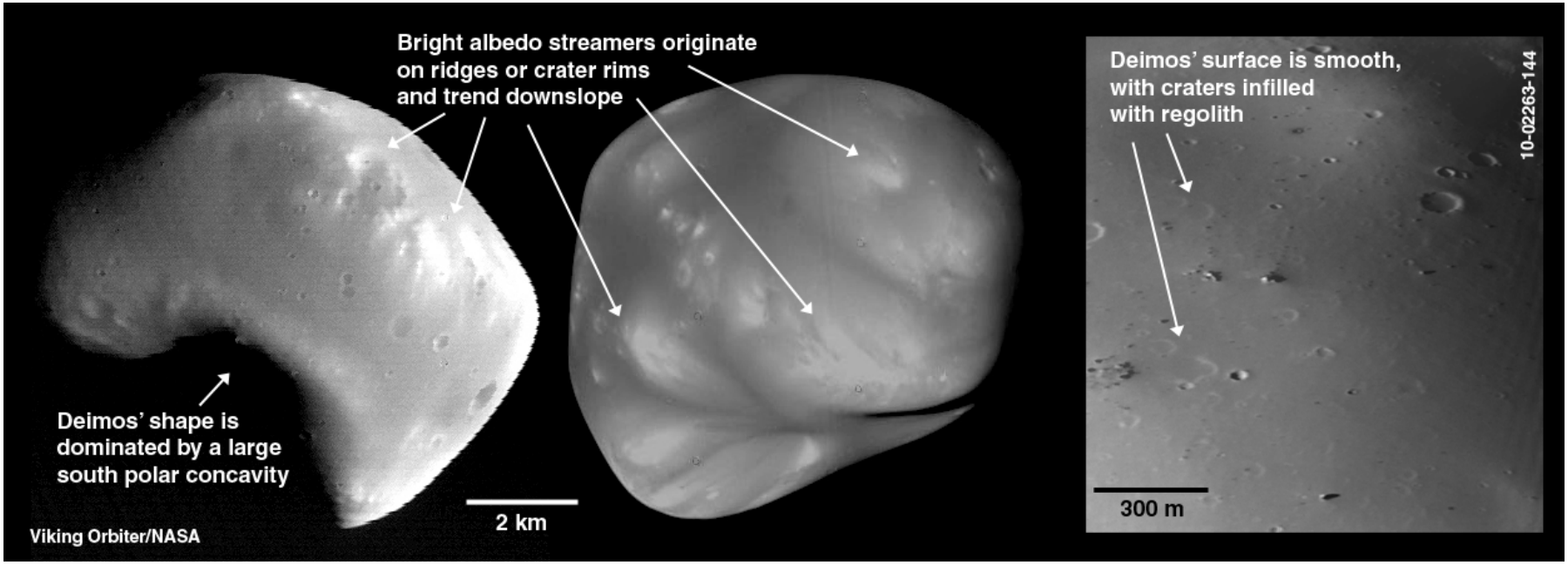
Are they water-rich, carbon-rich bodies?

- Spectrally, Deimos is D-type and may be carbon and volatile-rich
- Remote measurements are ambiguous about composition
- Need *in situ* composition measurements to understand the D-type objects and characterize C-containing materials

Kaidun Meteorite

What processes were important in Deimos' evolution?

- Impacts?
- Space weathering ?
- Material exchange with Phobos/ Mars or other extinct martian moons ?



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MERLIN Traceability to *Visions and Voyages*

Questions about Phobos / Deimos	*Visions and Voyages* Primitive Bodies Questions	Relevant Measurements
What are Phobos' and Deimos' origin and relationship to other solar system bodies?	What were the initial stages, conditions and processes of solar system formation?	Elemental composition
		Mineral abundance
		Shape and volume
		Mass and mass distribution
Do Phobos and Deimos contain water and carbon, and in what form?	What governed the supply of water to the inner planets? What were the primordial sources of organic matter?	Occurrence and abundance of hydrated minerals
		Occurrence and abundance of C phases
		Abundance of elemental C
What geologic processes that have shaped Phobos' and Deimos' surface and regolith?	How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time?	Characterize regolith movement and gradation
		Determine processes by which grooves form
		Determine how space weathering alters regolith properties

	Elemental measurement (APXS)		Mineralogical measurement (Raman spectroscopy)		Imaging (orbital color/ morphology, landed panoramic / microscopic)		Radio science

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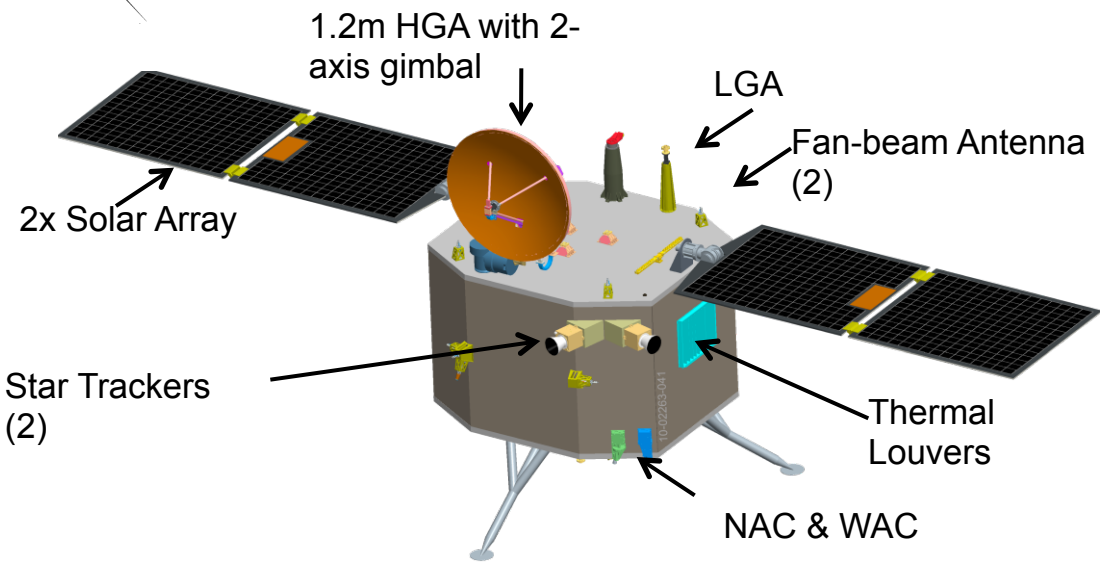
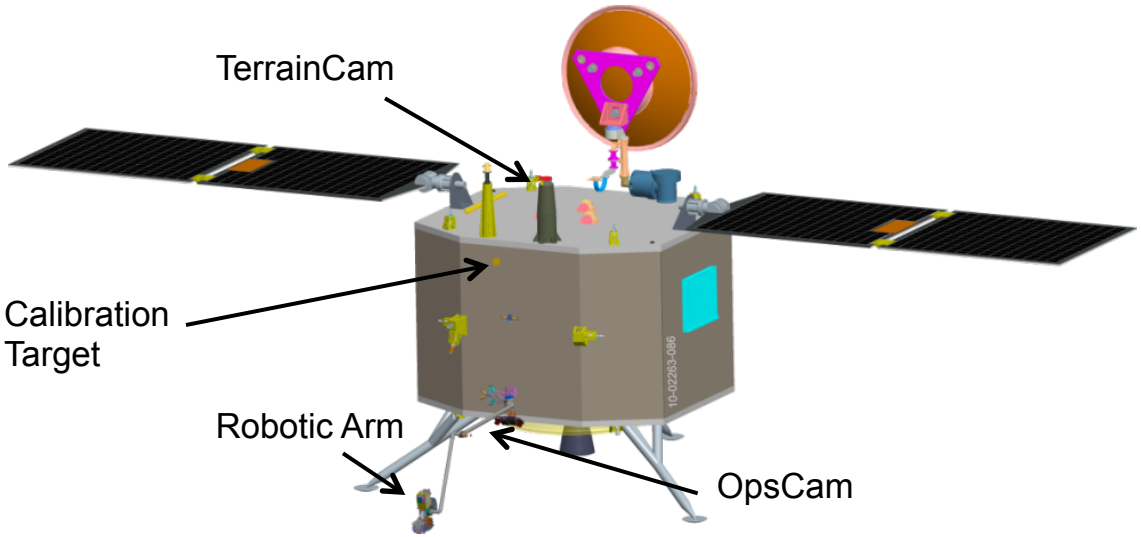
MERLIN Spacecraft





Highlights:

- Requires DV 1900 m/s incl. margin
- Bipropellant propulsion system
- 3-axis stabilized
- 120-kg Li-ion battery for 15-hr night
- Same design can target Phobos with smaller battery, tanks filled

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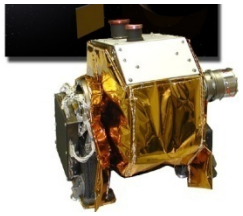
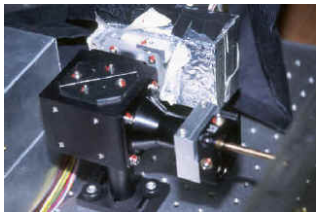
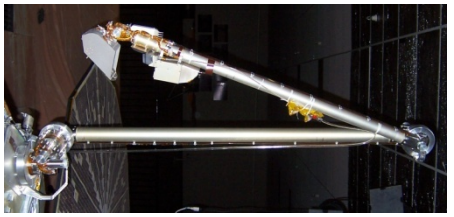
MERLIN Payload

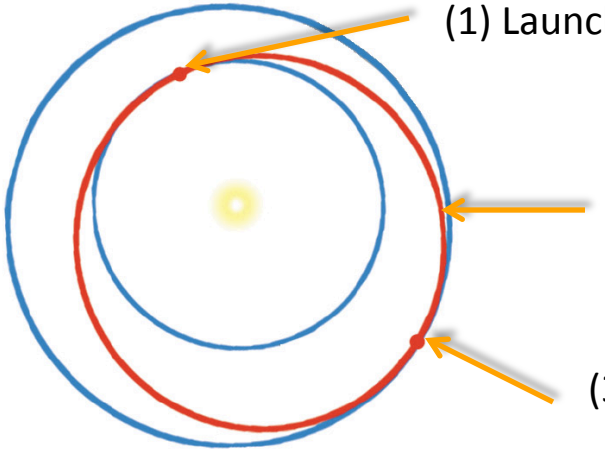




Investigation	Description, Heritage	Data Taken
Body Mounted		
DDIS: Deimos Dual Imaging System	NAC: monochrome WAC: 11 spectral and 1 clear filter Based on MESSENGER MDIS/ NAC, WAC without gimbaling	Stereo mapping/ OpNav: global 1 m/pixel; 5 cm/ pixel during low flyovers Color mapping: global 10 m/pixel; 20 cm/pixel during low flyovers; descent imaging 1 mm/pixel
TerrainCam, OpsCam Stereo Cameras	TerrainCam: 820 µrad/pixel, with azimuth articulation OpsCam: Stereo, 123° FOV, 2.1 mrad/ pixel; Based on MER/Navcam, Hazcam	Stereo imaging of workspace to support arm operations; imaging at multiple photometric angles; local panoramas
Arm-mounted		
APXS: Alpha Particle X-ray Spectrometer	Measures α and X-ray fluorescence from ^{244}Cm source; Based on MER/MSL APXS	≥ 3 landed elemental abundance measurements in α and X-ray modes
MRS: MERLIN Raman Spectrometer	Laser scatter peaks at wavelengths diagnostic of minerals, C-phases	Sample of ≥100 landed infocus spectra in arm workspace
MAC: MERLIN Arm Camera	Microscopic imaging, with LEDs for three-color imaging; Adapted from SM-4	Microscopic and synoptic color imaging of arm workspace
Optional Enhancements to Address Human Exploration Strategic Knowledge Gaps		
Dosimeter	Measures radiation dose; Based on RBSP	Low-rate measurements of total dose
Dust counter	Measures dust; Based on New Horizons	Times and magnitudes of particle impacts

MERLIN Mission: Cruise Phase



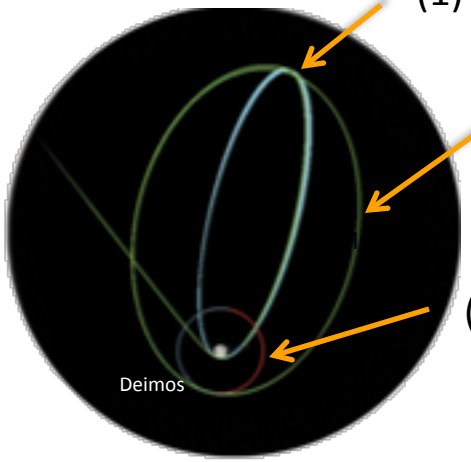
Cruise to Mars

(1) Launch, C3 ~10.8 km^2/s^2

(2) 28-month cruise on type IV trajectory, 1½ orbits around Sun

(3) Mars orbit insertion saves >600 m/s compared with type I

MERLIN Mission: Transition Phase



(1) Initial orbit around Mars, crossing both moons' orbits

(2) Raise periapse to transition orbit

(3) Lower apoapse to moon's orbit

MOI and Transition to Orbit at Deimos

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MERLIN Mission: Rendezvous Phase

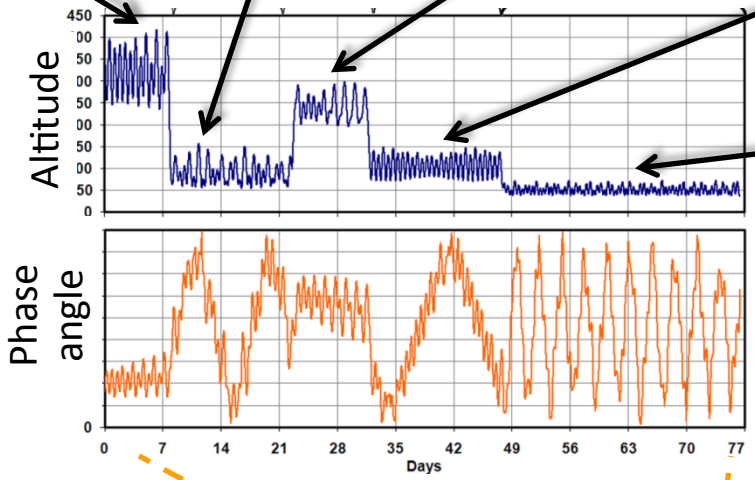
Initial gravity, shape, color

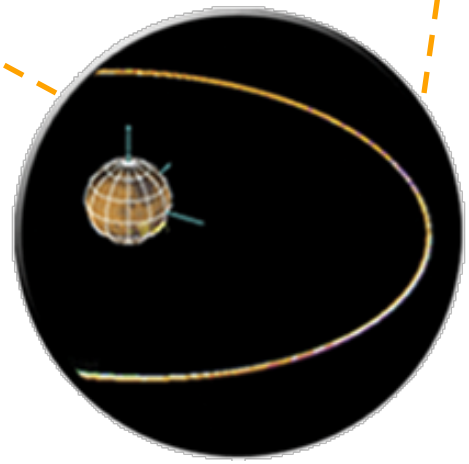
Refined gravity, shape, color; photometry

High phase for shape

Second color/photometry/ shape period

Gravity and high-res. color/stereo





Proximity Operations (Nearly Co-orbital with Deimos)

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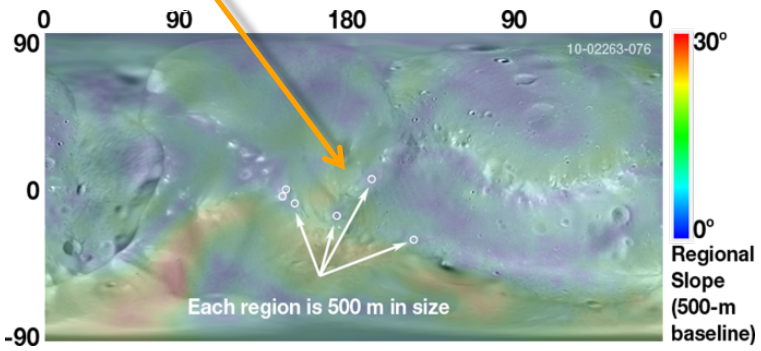
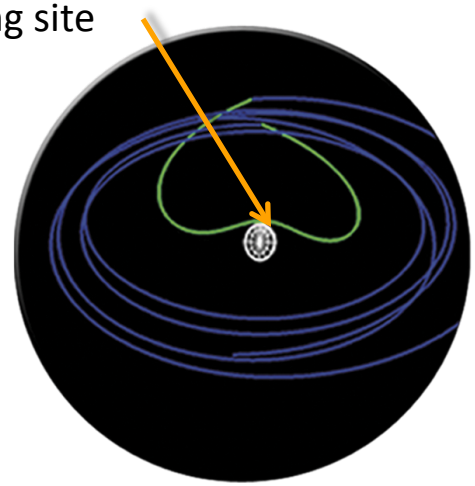
MERLIN Mission: Low Flyover Phase

Possible landing sites (selected prior to launch) characterized during low flyovers



3 weekly 1- to 2-km flyovers to certify landing site

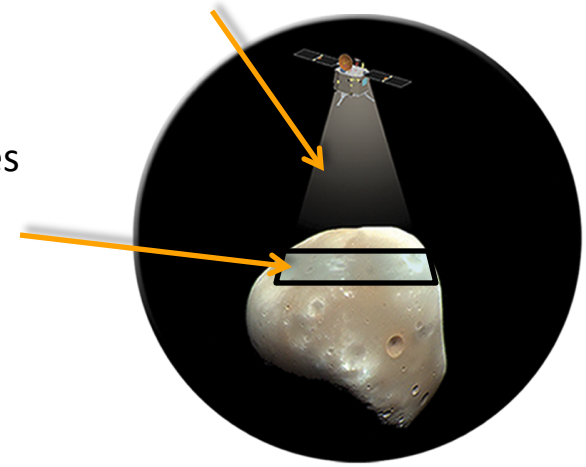


Deimos Flyovers

MERLIN Mission: Landing / Landed Ops

During landing, images used for terrain navigation are downlinked real time

Landed investigation takes ~60 days. The spacecraft can “hop” to 1 or 2 additional sites.



Landing and Landed Operations

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MERLIN Fills Strategic Knowledge Gaps

MERLIN Measurements	Human Exploration Strategic Knowledge Gap Addressed
Measure abundances of major, minor elements using APXS	Regolith elemental composition
Measure abundances of major mineral phases using MRS	Regolith mineralogical composition
Constrain regolith heterogeneity using high resolution color imaging by DDIS/WAC during low flyovers, descent	
Measure global shape using stereo imaging by DDIS/NAC	Shape model, pole, rotational state
Image in stereo morphologic features indicative of regolith processes using DDIS/NAC	Regolith mechanical properties High-resolution terrain model
Determine regolith texture with imaging by TerrainCam, MAC	
Constrain space weathering by repeating Raman measurements at surface and after excavating 1 cm	
Nested descent images during landing to locate landing site	Plume effects on regolith
Measure mass and mass distribution using Doppler tracking	Small body gravitational field
Measure abundances of H_2O, OH-bearing phases w/ MRS	Volatiles and potential for *in situ* resource utilization
Measure abundances of C-bearing phases w/ MRS	
Measure content of C w/ APXS	
Bound radiation effect on space weathering /measuring dose	Human tissue effects
Constrain density of dust belts using dust counter	Mars orbital debris environment